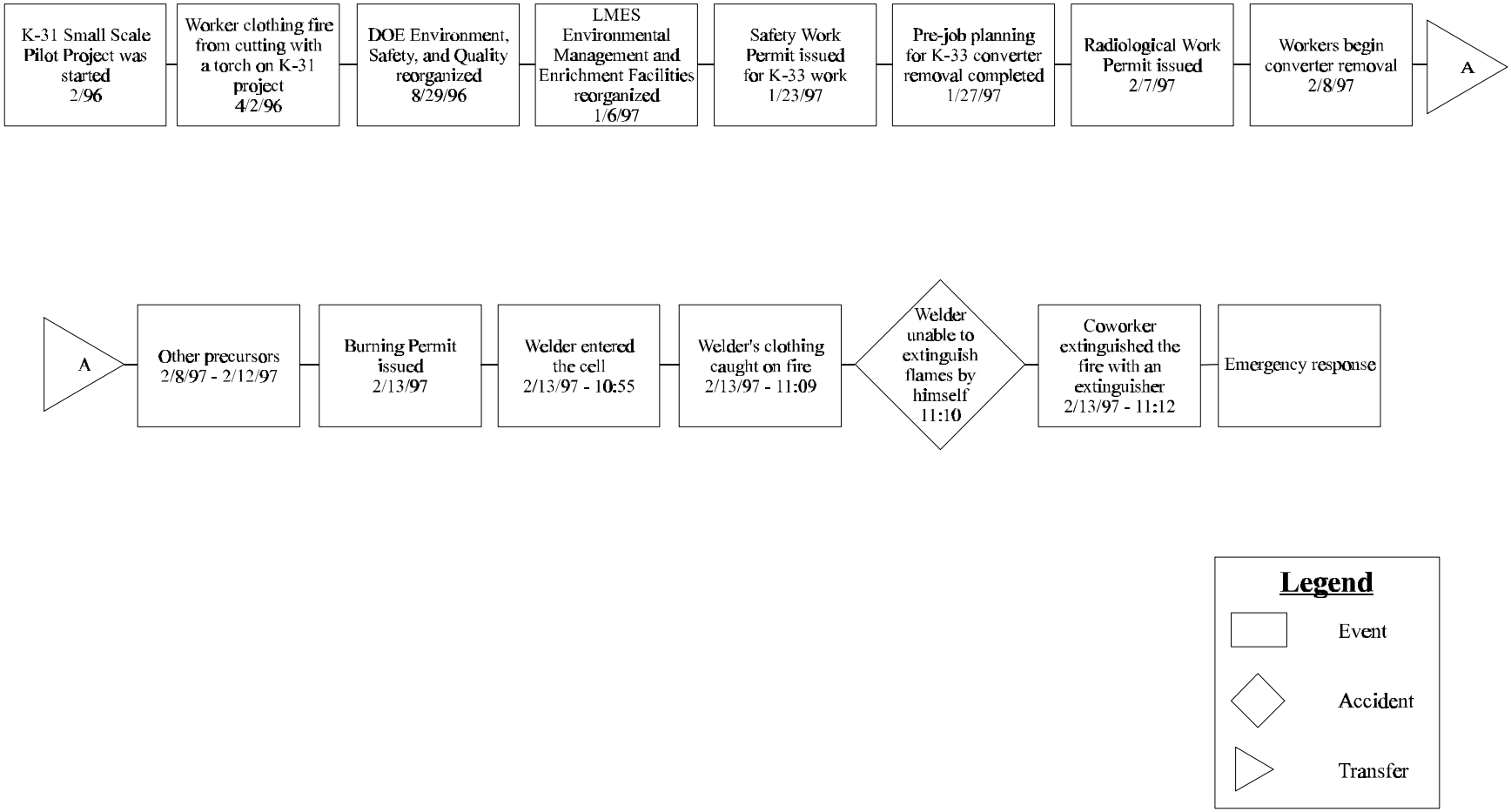

Figure 2-2. Summary Events Chart and Accident Chronology

The Welder was examined and surveyed by Radiation Emergency Assistance Center team members and was free of radioactive contamination. Emergency physicians and surgeons managed his medical care in the Emergency Department, and a general surgeon continued medical and surgical management in the Intensive Care Unit. After 4½ hours of stabilization care, the decision was made to transfer him to Erlanger Burn Center in Chattanooga. Air transport was requested through rotary and fixed-wing carriers, but could not be done because of icy weather. Ultimately, ground transport was arranged for the patient transfer to Erlanger.

The Welder was burned over 95 percent of his body. He died the next day.

The Welder suffered third-degree burns over 95 percent of his body. He died at 10:41 a.m. on February 14, 1997, from acute respiratory distress syndrome.

The overall quality of the accident response effort on February 13, 1997, was satisfactory and provided the Welder opportunity for survival, if his burn wounds had not been so extensive. However, egress from Cell 7 was problematic because of poor illumination and the confined nature of the work site. The difficult extraction from the cell/building accounted for delay in transport to the Medical Center. Twenty minutes of the rescue time were spent getting patient-removal gear to Cell 7 and maneuvering the stretcher-borne, 215-pound Welder over and under pipes. A nearby cell panel opening also had to be enlarged for egress. Without the obstacles, the egress difficulties from Cell 7, the physical distances involved, and the lack of basic first-aid gear in the building, the extraction time could have been shortened by approximately ten minutes.

Overall accident response was satisfactory. Quicker evacuation of the victim, while possible, would not have changed the outcome.

LMES took prompt, appropriate, and effective actions following the accident to preserve the integrity of the accident scene, collect evidence, and prepare for an accident investigation. The investigative readiness of LMES met the requirements of DOE Order 225.1, *Accident Investigations*.

The contractor took appropriate actions in maintaining the accident scene.

2.2 HAZARDS, CONTROLS, AND MANAGEMENT SYSTEMS

A review of previous occurrences at K-25 reported in DOE's Occurrence Reporting and Processing System since 1991 revealed that the leading root causes were management systems and personnel error. There has been one Type A accident investigation at K-25 since 1991 (November 22, 1992, fatality) and five Type B investigations. The root causes of the November 22, 1992, fatality were that line management did not establish responsibility for safety, effective work controls were not used, and the safety culture

resulted in hazards going unrecognized.

The Nuclear Regulatory Commission, Naval Reactors Program, National Institute of Science and Technology, National Fire Protection Association, and National Safety Council were contacted and indicated that they knew of no reported incidents involving ignition of anti-contamination clothing with resultant fatalities during cutting and welding operations. A 1988 Occupational Safety and Health Administration (OSHA) report on selected cutting- and welding-related fatalities identified only one fatality from clothing ignited by sparks and molten metal. The report covered 217 cases involving 262 fatalities from 1974 through 1988. Review of recorded DOE occurrences indicated that none involved fatalities in cutting and welding operations due to normal or anti-contamination clothing fires.

Records of six agencies, plus the DOE, indicated only one similar fatality.

2.2.1 Industrial and Worker Safety

The following facts relate to industrial and worker safety issues that had an impact on the accident:

Personal Protective Equipment (Clothing Flammability)

- The Welder was wearing personal protective equipment, as previously noted in Section 2.1.1. OSHA requirements in the Federal regulations for personal protective equipment do not specify a need for fire-retardant clothing for welding/cutting operations.

Fire-retardant clothing was not required or used.

- The blue general-purpose coveralls met the requirements of 16 CFR 1610 for normal flammability, Consumer Products Safety Commission Class 1 clothing ("having no unusual burning characteristics" as "generally accepted by the trade"). The anti-contamination coveralls met LMES specifications for such clothing (MS-HPD-001-A) and had no flammability requirements specified. Some LMES personnel believed that the company-issued, anti-contamination clothing was fire-retardant. This misinterpretation may be a result of the LMES clothing specifications for the blue general-purpose coveralls (Consumer Product Safety Commission Class 1, normal flammability). However, this classification only requires that the clothing have no unusual burning characteristics and is designed only to eliminate the use of any “dangerously flammable clothing textiles” in ordinary clothing.

- Flammability of the company-issued, blue general-purpose coveralls was first raised as an issue at the monthly K-25 Company-Union Safety Advisory Committee meeting in January

1995. As a result:

- In April 1995, Norvell Corporation representatives met with maintenance, safety, welder, and union representatives to discuss the use of flame-retardant blue coveralls. Several pairs of flame-retardant blue coveralls were ordered to be used by electricians, welders, and maintenance mechanics on a trial basis.

- At the September 1995 K-25 Company-Union Safety Advisory Committee meeting, union representatives reported that the blue coveralls, worn by six different welders, were scratchy and hot, even after laundering. They also noted that sparks from welding operations penetrated the fabric more easily and more often than the current, company-issued, non-flame-retardant blue coveralls. At that time, it was decided to continue using the company-issued blue coveralls, and the issue was closed.

■ Flammability of the company-issued, anti-contamination coveralls was raised in a monthly K-25 Company-Union Safety Advisory Committee meeting in May 1995.

- At the meeting, a union representative displayed a sample pair of the fire-retardant, anti-contamination coveralls obtained from Norvell. These coveralls were pure cotton and were treated with a fire retardant. The material was guaranteed by the manufacturer for 25 industrial washes as long as chlorine bleach was not used. These anti-contamination coveralls were similar to those used at other DOE sites, such as Portsmouth and Paducah.

- The sample pair of fire-retardant, anti-contamination coveralls was placed in the Industrial Safety Office for the workers to view. However, no records indicate the final disposition of this issue. It appears that neither the Committee, the Union, nor LMES revisited this issue after May 1995.

- Neither the general-purpose nor the anti-contamination coveralls were fire-retardant. (See Section 2.3 for the results of clothing tests conducted by an independent testing laboratory at the request of the Board.)

- The personal protective equipment specified on the Radiological Work Permit was consistent with that for a high- contamination area, as described in the LMES K-25 *Site Radiological Control Program Manual* and in Procedure RCO-AP-8.02, *Radiological Work Permits*, Revision 1, Appendix A, *Anti-Contamination Clothing Guidelines*.

- National Fire Protection Association Standard 51B, *Safety in Cutting and Welding Operations*, does not identify requirements for personal protective equipment for cutting, welding, and brazing.

Work Permits

- A Safety Work Permit (SWP), a Radiological Work Permit, and a Burning Permit were prepared for the work being performed. The SWP for the welding work in Cell 7 indicated that site fire protection staff would conduct a site evaluation. However, there was no evidence that an in-cell evaluation was conducted. The responsible fire protection engineer for the Cell 7 hazard evaluation did not view the work site inside the cell prior to signing the SWP.

Although required in the permit process, no work site fire hazard evaluation was performed, and no fire watch was assigned.

- The Burning Permit for the day of the accident did not identify a fire watch for the work. According to the Service Supervisor, he orally assigned four maintenance mechanics to the Cell 7 work, including fire watch duties. However, because the Service Supervisor did not attend the daily safety meeting, the Board has no evidence that these instructions were given. According to the maintenance mechanics, they were not aware that they had been assigned fire watch duties. In addition, none of the maintenance mechanics were inside the cell at the time of the accident.

- The bases for posting the area inside the cell as a high-contamination area were radiological surveys performed by the Radiological Control Organization and possible contamination resulting from cutting into the radiologically contaminated process system.

- Evidence indicated that radiological control technicians performed continuous coverage of the work as required by the Radiological Work Permit.

HEPA Filter Placement

- The Radiological Work Permit required that a radiological control technician check the placement of the high-efficiency particulate air (HEPA) local exhaust ventilation, which had to be within one foot of cutting, grinding, and burning operations. There was no evidence that this check was completed prior to the accident.

- The Board's review of the accident scene revealed that the HEPA local exhaust ventilation vacuum unit on the east side of Cell 7, and its associated hose, could not be properly placed from outside the cell, nor could it reach the work area on the east side of Converter 4.

    - Five clamps had already been cut on the east side of Converter 4 at the time of the accident.

    - The position of the HEPA unit, the use of the east side access panel for Converter 3, and the length of the hose available (approximately 15 feet) indicate that the HEPA local exhaust ventilation was not being used at the time of the accident or prior to the accident when the five clamps were cut.

The HEPA filter was not used as required by the permit.

OSHA regulations and guidance emphasize that, whenever possible, engineering controls to reduce exposure to workers must be evaluated and implemented before administrative procedures and personal protective equipment are deployed. LMES Program Description, SH-152PD, *Occupational Safety and Health Program*, Section 4, states that the order of precedence for this process is: (1) substitute less hazardous processes, (2) apply engineering controls, (3) use administrative controls, and (4) use personal protective equipment.

The contractor's safety program emphasized use of personal protective equipment over the implementation of engineering controls.

All previous converter removals were similar, which would facilitate the design and use of easily movable welding shields or enclosures

to minimize the spread (distribution) of slag from this cutting. Alternative methods (other than using a torch) could also have been substituted. These engineering controls and alternative processes apparently were not considered because of the emphasis placed on the use of personal protective equipment.

Most fire protection and cutting/welding standards, including DOE and LMES standards, concentrate on the property protection aspects of the hazards and do not specifically address the need for and the type of personal protective equipment to resist flame and heat. However, OSHA requirements do indicate that personal protective equipment should be appropriate for the hazards being encountered.

The only standard found that was relevant to fire-retardant personal protective clothing is the American National Standards Institute (ANSI) Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*. This standard recommends that heavier-weight materials, such as wool or heavy cotton, which are more difficult to ignite, be worn during cutting and welding work. It further recommends that cotton be chemically treated to reduce its combustibility and warns that washing may reduce fire retardancy. It also offers specific construction recommendations for clothing used in cutting and welding to reduce the clothing's ignition potential, such as no cuffs or uncovered pockets. However, this standard is not a mandatory DOE standard, nor is it referenced as an applicable standard in OSHA Federal regulations regarding personal protective clothing.

One national consensus standard found on flame-retardant clothing is not mandated by DOE or referenced as applicable by OSHA.

The emphasis on property protection also minimizes the importance of training fire watch personnel in alternative methods for extinguishing a fire, such as the drop-and-roll method or enveloping a person in a heavy woolen "fire blanket" to smother the flames.

No regulatory, DOE, or LMES requirements for fire-retardant clothing were applicable to the fire hazards associated with the work being performed in Cell 7 at the time of the accident. However, some specific fire protection concerns inherent in the work activities to be performed within Cell 7 required professional evaluation (e.g., fire extinguisher placement and inspection and Life Safety Code considerations) but were not adequately reviewed by fire protection staff. The fire potential represented by the combustible clothing worn by the welders may not have been recognized by the fire protection staff unless they witnessed the clothing burn tests or had been advised by the welders that their clothing had caught on fire during previous jobs. Neither was the case here.

No regulatory, DOE, or LMES requirements for use of fire-retardant clothing exist.

The K-25 Company-Union Safety Advisory Committee has reviewed issues related to personal protective equipment since at least 1993. In 1994 and 1995, OSHA implemented new requirements for the flammability of electrical workers' personal protective equipment. The Committee, after input from the workers who evaluated sample materials, decided not to use the flame-retardant, blue general-purpose coveralls and opted to continue using their current coveralls. Flame-retardant anti-contamination clothing was also reviewed at a Committee meeting in May 1995. However, based on interviews, the Board determined that the minutes from the meeting were not totally correct. In 1995, the Committee evaluated anti-contamination clothing from the perspective of heat stress, not flammability. A sample made available to the union members also happened to be flame-retardant. However, the Committee did not recognize the importance of the flammability issue for the anti-contamination clothing; therefore, the issue was not pursued.

The site's contractor/union safety committee evaluated anti-contamination clothing from the perspective of heat stress, not flammability.

The *K-25 Site Radiological Control Program Manual* was developed in accordance with the *DOE Radiological Control Manual* (DOE/EH-0256T, Revision 1). It identifies the actions necessary to ensure proper interpretation and implementation of all provisions of regulations and regulatory guidance relevant to the K-25 Site Radiological Control Program.

The following requirements in the *K-25 Site Radiological Control Program Manual* were consistent with the guidance of the *DOE Radiological Control Manual*:

The LMES Radiological Control Program Manual limits multiple levels of personal protective equipment from a waste minimization standpoint only.

- "Protective clothing, as prescribed by the RWP [Radiological Work Permit] is selected based on the contamination level in the work area, the anticipated work activity, worker health considerations, and regard for nonradiological hazards that may be present.

- "The use of personal protective equipment or clothing (including respiratory protection) beyond that permitted by the RCO [Radiological Control Organization] for radiological control purposes detracts from work performance and is contrary to ALARA [As Low As Reasonably Achievable] principles and waste minimization practices. Such use is not authorized.

- "Company-issued clothing, such as work coveralls (blue's, scrubs, or khaki's) and shoes, are considered the same as personal clothing and are not used for radiological control purposes.

- "Outer personal clothing are [sic] not to be worn under anti-C [anti-contamination] clothing: (1) for entry into High General Area Removable Contamination Areas, (2) during work conditions requiring splash resistant anti-C [anti-contamination] coveralls, or (3) during work conditions requiring two pairs of anti-C [anti-contamination] coveralls."

Guidance for Personal Protective Equipment Programs is addressed in 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response*, Appendix C, *Compliance Guidelines*, which states "[t]he use of PPE [personal protective equipment] can itself create significant worker hazards, such as heat stress, physical and psychological stress, and impaired vision, mobility, and communication. For any given situation, equipment and clothing should be selected that provide an adequate level of protection. However, over-protection, as well as under-protection, can be hazardous and should be avoided where possible."

The use of blue general-purpose coveralls, worn by workers in Cell 7 on the day of the accident, was not prescribed by the Radiological Work Permit prepared and used for the work.

A Radiological Work Permit is an administrative mechanism that establishes the radiological controls to be used in conducting radiological work activities. It describes the scope of the work to be performed, required personal protective equipment, radiological survey data applicable to the work area, and other pertinent special instructions. It does not appear that consideration was given to risks for fire hazards during welding and burning operations associated with (1) using multiple layers of personal protective clothing (e.g., anti-contamination clothing) and (2) using blue general-purpose coveralls, in addition to the personal protective equipment prescribed by the Radiological Work Permit. Use of the radiological personal protective clothing appears to have been based primarily on the contamination level inside the cell rather than on consideration of all potential hazards, such as fire.

The Radiological Work Permit did not address risks from the use of multiple levels of personal protective equipment.

Implementing the requirements of the K-25 *Radiological Control Program Manual* in the work controls, planning for the welding and burning work at K-33, evaluating the potential hazards associated with the use of multiple layers of anti-contamination clothing, and prohibiting the use of the blue general-purpose coveralls under the anti-contamination coveralls would not have precluded the Welder's anti-contamination clothing from catching fire. However, it might have permitted the Welder to recognize that he was on fire earlier than he did. Although 29 CFR 1910.120 applies to hazardous waste

operations and emergency response, it was the only guidance that considered the use of personal protective equipment as a potential hazard to workers. The Board was unable to locate any Federal regulations, DOE Orders/rules, or LMES K-25 policies that addressed the application of radiological personal protective equipment for welding and burning operations inside radioactive contamination areas.

Limiting multiple levels of personal protective equipment would not have prevented the fire, but might have allowed the Welder to know more quickly that his clothing was on fire.

2.2.2 Work Planning and Controls

The DOE Implementation Plan for Integrated Safety Management, dated April 18, 1996, states that safety management activities can be grouped into five core safety management functions:

- Define the scope of work
- Identify and analyze the hazards associated with the work
- Develop and implement hazard controls
- Perform work within controls
- Provide feedback on adequacy of controls and continuous improvement in defining and planning work.

These five core safety management functions provide the necessary structure for any work activity that could potentially affect the public, the workers, and the environment. The degree of rigor needed to address these functions varies with the type of work activity and the hazards involved. An analysis of work planning and controls for the K-33 converter work applicable to the accident in relation to the five core safety management functions follows.

Define the Scope of Work

LMES used a maintenance job request to define the scope of the work to be performed. However, the Board found that line management responsibility and accountability for safety was lacking at both the Oak Ridge Operations Office and LMES. Within the Operations Office, no organization or individual assumed or was assigned the responsibility for managing and monitoring the work to be performed at K-33. Within LMES, the Board found that organizations and individuals responsible for the building/facility were not involved in planning the work and therefore were unaware of any impact the work might have on their safety envelope. No single organization within LMES served as a focal point to ensure that all hazards were identified, safety permits were prepared in accordance with LMES procedures, and appropriate hazard controls were put in place. As a result, no complete work package was developed that adequately translated the job mission into work, set

Five core safety management functions for work planning/control were analyzed.

As a result of a lack of clarity

safety expectations, and prioritized tasks. In addition, because of a recent reorganization and downsizing, personnel with adequate training or experience were not assigned to the job.

in line management responsibility and account-ability for safety, an incomplete work package was prepared.

Identify and Analyze the Hazards Associated With the Work

OSHA [in 29 CFR 1910.132(d)] requires the employer to assess the workplace to determine whether hazards are present, or are likely to be present. These regulations also require that "the employer shall verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated; the person certifying that the evaluation has been performed; the date(s) of the hazard assessment; and which identifies the document as a certification of hazard assessment."

K-25 Site Standard Practice Procedure, "Safety Work Permit SPP-5401," Revision 3 (Change 5, effective date November 27, 1996) states that the issuing authority (i.e., the individual authorized to have operating jurisdiction over the equipment or facility where the work covered by the permit was to be performed) "will determine the safety requirements by using job safety analysis, safety plans, and any other approved documents as an aid." However, the responsibility to ensure that a Job Hazards Analysis has been performed in accordance with LMES Instruction SH-118INS, Revision 0, dated July 10, 1996, is not clearly identified.

A number of sources mandate the need for a Job Hazards Analysis for the type of work performed in the K-33 cell, but none was performed.

LMES Instruction SH-118INS describes the process for conducting a Job Hazards Analysis, provides guidance regarding conditions under which a new Job Hazards Analysis should be performed, and states that the "supervisor" is responsible. The process described by this instruction includes assembling a multidisciplinary team of workers and safety professionals, documenting individual work steps for the job, identifying the hazards for each step, and specifying the controls for each hazard. A Job Hazards Analysis to this level of detail was not performed for SSMRP, and no Job Hazards Analysis was performed for the K-33 converter removal.

During the SSMRP work at K-31, industrial safety/industrial hygiene personnel were permanently assigned to the job and monitored the actual cutting operations at the work site to evaluate the hazards and controls for the work.

LMES Instruction SH-118INS contains adequate guidance for performing a Job Hazards Analysis. However, the individual responsible (issuing authority or supervisor) for ensuring that a Job Hazards Analysis has been or is to be conducted in accordance with

this instruction is not clearly defined. Consequently, such a Job Hazards Analysis was not performed for the K-33 converter removal work. It is the Board's judgment that a properly conducted multidisciplinary Job Hazards Analysis in accordance with LMES Instruction SH-118INS, with experienced workers participating, might have identified all the hazards to the Welder.
In this case, because of an unclear assignment of responsibility and because of lack of specific guidance with regard to the identification of routine/non-routine work, no Job Hazards Analysis was performed.

It should be noted that the Board conducted a multi-agency search for other instances where a welder died due to ignition of his or her clothing. Only one such incident was found in private industry, possibly leading to a widespread lack of appreciation concerning the hazards involved in this welding/cutting operation. Since workers had not reported earlier clothing fires, supervisors had not recognized the rather frequent occurrence of such fires, and there was little indication of a similar hazard in the literature. The recognition of the interrelationship between the fire hazard and the personnel protective equipment required for this job would be dependent on the intelligence and forethought of those conducting the analysis.

No individual was assigned responsibility for ensuring the conduct of a Job Hazards Analysis.

Develop and Implement Hazard Controls

The work documents prepared during planning for the K-33 converter removal work included a Maintenance Job Request, a Radiological Work Permit, an SWP, and a Burning Permit. The permits specified the hazards controls for the work. Review of these documents revealed that:

- The Radiological Work Permit required the use of anti-contamination clothing. However, the personal protective equipment specified for the Welder did not meet the criteria that it be based on the anticipated work activity, worker health considerations, and regard for the non-radiological hazards that may be present, as required by the K-25 Site *Radiological Control Program Manual.*

- A task-specific work plan was not prepared for K-33 converter removal work, because the work was classified as "routine maintenance" within the "skill of the craft"; consequently, K-25 Site Maintenance Division Administrative Procedure MDP-AP-0002, Rev. 5, dated January 1, 1996, did not require a work plan. This procedure did not contain adequate criteria for

The work documents dealt

identifying maintenance work that is routine versus non-routine and/or within the "skill of the craft." Appropriate criteria are necessary to ensure that a task-specific work plan is prepared, when appropriate, based on the complexity of the work and the hazards that are present.

inadequately with safety issues, such as administrative and engineering controls, lighting, and fire watch.

- The work documents specified no alternative cutting methods, engineered controls, or specific personal protective equipment to protect the workers from sparks or hot slag generated during cutting operations. The work documents contained no provisions to ensure adequate ingress and emergency egress for personnel or equipment, even though the cell had only one entrance, and human entry through that entrance was restricted by the piping configuration. Removal of roof panels and side panels was also necessary for equipment removal.

- The work documents did not require installation of lighting inside K-33, Cell 7, which had no lighting prior to the start of work. Additional lighting was installed as a result of oral direction from Industrial Safety/Hygiene. However, after the work started, the adequacy of lighting was not evaluated either for the work being performed or for personnel egress in an emergency.

- Although required by LMES Procedure ESS-FP-111 (Rev. 1), a fire watch was not identified on the Burning Permit for the work being performed on the day of the accident. A fire watch is a designated individual trained in fire-watch duties, who, for welding/cutting activities, is required to be dedicated to this task. Reviews of three other Burning Permits for work in the cell on the days prior to the accident revealed that two did not have a fire watch identified. The service supervisor in charge of the work is responsible for identifying the fire watch on the Burning Permit.

Converter removal work was sufficiently complex, with a variety of personnel hazards, to require preparation of a task-specific work plan. Had the work not been classified as "routine maintenance" and within the "skill of the craft," a work plan might have been prepared, and adequate provisions for concerns such as lighting and ingress/egress could have been specified. The work plan also could have provided a means to convey lessons learned during past work (such as that for the SSMRP at K-31) to the workers involved in K-33 converter removal.

Classifying the work as "routine" may have circumvented the consideration of some hazards and controls.

It is the Board's judgment that LMES procedures do not contain adequate criteria for identifying maintenance work that is routine

versus non-routine and/or within the "skill of the craft." In this case, the complexity of the work, the relative unfamiliarity of the welders with performing tasks in the prescribed protective equipment, and the significant differences between the K-33 configuration and that of the more recent similar work would seem to make dependence on "skill of the craft" questionable. In addition, some hazard controls that were identified for the work were not implemented.

Perform Work Within Controls

The Board could find no evidence of a pre-job safety meeting that included the Service Supervisor, all the craft disciplines, and appropriate safety personnel assigned to monitor the work.

A number of specified controls were bypassed.

The Welder wore his blue general-purpose coveralls beneath two sets of anti-contamination clothing. This is prohibited by the *K-25 Site Radiological Program Control Manual*, Attachment 2 to Section 3.8.

Burning Permits, issued for converter removal work from February 11 to 13, 1997, were to be signed by the Service Supervisor and the Issuing Authority indicating that the precautions identified had been fully implemented and verified. On the day of the accident, the Service Supervisor signed in both capacities. The Board considers the Issuing Authority as the single point of contact responsible for the safety of all work to be performed, and this individual should have performed the verifications and signed the Burning Permit, along with the Service Supervisor. In addition, the verification spaces on the form were not checked; moreover, the Supervisor had not been at the work area (K-33, Cell 7) on February 13, 1997, prior to the accident, where he would have to go to determine whether the precautions identified on the Permit had been fully implemented.

No fire watch was identified, nor was a fire watch present in the cell at the time of the accident, as required by LMES procedures.
The Industrial Hygiene Department was not notified prior to cutting operations. Consequently, the industrial hygiene surveys, required by the SWP, were not accomplished.

As noted above, several actions specified by the work documents were not performed. Had the workers been adequately supervised, these actions could have been accomplished and appropriate controls placed on the work.

Provide Feedback on Adequacy of Controls and Continuous Improvement in Defining and Planning Work

Interviews revealed that the work being performed at the time of the accident was considered similar to that previously performed during the SSMRP at Building K-31 in 1996. Both jobs involved the cutting of piping and support structures and removal of converters using an overhead crane. During the SSMRP work, an entire cell (ten "00" converters, compressors, motors, and associated piping and supports) was removed. A task-specific work plan was included as a part of the SSMRP Maintenance Job Request. The work was initiated on May 15, 1996, and completed on July 3, 1996. Because it had been several years since major removal of equipment, the work at SSMRP was fully planned and documented to enable application of lessons learned to future similar work. However, the two jobs differed in several ways. For K-33 converter removal work, the cell walls remained in place, while for SSMRP, the exterior walls were removed before cell equipment was disassembled. The equipment in K-33 was also much larger than in K-31. Another key difference was that the equipment from K-33 was to be reinstalled in a nuclear facility, while for K-31, the metal was to be recycled.

Though different in key ways, the work in K-33 was considered similar to previous work in K-31.

A project report, prepared at completion of the SSMRP work, documented lessons learned during the SSMRP work. These lessons learned included the need for developing and using a work plan for future similar work, developing specialized cutting tools, not assigning fire watches, and reducing anti-contamination coverall requirements to one pair rather than two during burning/cutting operations. There was no evidence that either the SSMRP project report or the lessons learned from the project were used by personnel involved in the K-33 work.

Lessons learned in the K-31 work were not applied to the work in K-33.

None of the maintenance workers assigned to K-33 converter removal had worked on the SSMRP. The supervisor had never supervised welders before, and he had not been trained on the use of Burning Permits.

Interviews revealed that anti-contamination clothing had caught fire in similar work during the SSMRP at K-31. Anti-contamination clothing also caught fire at K-33 due to molten metal (slag) dropping/splashing on the clothing. For example, several days before the accident, a welder's bootie caught fire, and the day before the accident, the Welder's shoulder sleeve caught fire, burned through both sets of anti-contamination clothing, and scorched his general-purpose coveralls. These and many similar incidents were

Welders' clothing had caught fire previously at both K-31 and K-33, but the incidents were not reported.

never reported as "near misses" through the occurrence reporting system, nor were they reported as injuries, since they resulted in either no burns or only minor burns.

Summary

An analysis of the facts leads to the conclusion that the maintenance work planning process and associated controls for the K-33 converter removal work did not ensure that an adequate Job Hazards Analysis was completed before the work began. Thus, measures and controls to mitigate the work hazards were not developed or implemented, and the work was not performed with appropriate controls.

In summary, the planning process for the K-33 work did not involve required analysis of hazards, did not assure adequate controls, and did not identify crucial lessons learned.

The absence of clearly defined line management responsibility and accountability for safety caused failures in translating the job mission into safe work practices, setting safety expectations, and allocating trained and experienced personnel. Since line management did not ensure that an adequate Job Hazards Analysis was completed prior to the work starting, measures and controls to mitigate the hazards for the work were not developed or implemented. In turn, this caused the work to be performed without appropriate controls. The requirements for this process were specified in LMES instructions and K-25 site procedures, but were not implemented during the work. Furthermore, lessons learned from previous work were not adequately evaluated, documented, or incorporated into the planning for K-33 converter removal work. If the problems workers experienced with anti-contamination clothing catching on fire had been adequately analyzed, and if the lessons learned had been documented, communicated, and appropriately incorporated into the planning for K-33 converter removal work, the accident might have been avoided. More fundamentally, weaknesses in the safety management system allowed the Welder's safety to depend on the single mitigating factor of a property-protection-oriented fire watch that, while required, was not routinely implemented.

The Board considered the limited history of fatalities associated with the ignition of anti-contamination clothing during welding/cutting operations, the lack of requirements regarding the use of flame-retardant anti-contamination clothing, and the failure of existing fire watch requirements to emphasize personnel safety responsibilities. Based on these considerations, the Board could not conclude that even a work planning/control process that met the five core management functions of the DOE Implementation Plan for Integrated Safety Management would have prevented this accident. However, the Board did conclude that without such a structured

work planning/control process, as was the case for the work being performed in Building K-33, the opportunity to identify the clothing fire hazard was not provided, thereby assuring that it would not even be considered.

2.2.3 Policies and Procedures

LMES Policy Statement ES-EH-100 was in place for the establishment and implementation of environment, safety, and health (ES&H) policies and to direct that all ES&H efforts be carried out cooperatively and with the degree of consistency specified in policies, standards, and procedures. LMES committed to conduct operations effectively, in compliance with applicable ES&H Federal and state laws, orders, and regulations, and in a manner consistent with the associated hazard. LMES Program Description SH-152PD further outlines the methods used to protect personnel in the fields of occupational safety, industrial hygiene, and fire protection. In the program description, LMES committed to implement this program for consistency with the requirements of Federal regulations, Lockheed Martin Corporation, Inc., policies, and applicable DOE Orders.

Relevant policies and procedures are in place but were not followed.

- LMES Procedure SPP-5401 describes the SWP process for the evaluation and control of potential, or actual, hazards associated with work activities, such as the removal of process equipment in the K-33 Building and the protocol for establishing appropriate protective measures.

- A Job Hazards Analysis was not used to determine the safety requirements associated with the converter removal work in Cell 7 as prescribed by Procedure SPP-5401.

- The issuing authority for the SWP did not review the work requirements and protective measures listed on the permit with the new Service Supervisor in charge of the work on the day of the accident to ensure that both were in agreement prior to issuing the Permit.

- There was no supervision to monitor the workers or the cell on the day of the accident to ensure that the tasks were completed in compliance with the SWP, as required by LMES Procedure SPP-5401.
- LMES Industrial Safety and Health, Industrial Hygiene, Fire Protection, and Nuclear Criticality Safety staff signed the SWP.

- In some instances, special instructions were documented on the

SWP by LMES safety and health staff (i.e., "Industrial Hygiene to monitor initial openings for hydrogen fluoride. Extended burning/welding may require carbon monoxide monitoring. Respiratory protection required during initial process equipment openings. Industrial Hygiene may perform sampling for metal exposure. Heavy equipment operation may require carbon monoxide. Notify Industrial Hygiene prior to starting work.")

- Not all LMES safety and health staff who signed the SWP entered the cell to evaluate and identify potential hazards and determine the necessary protection measures.

- Actual work performance did not comply with the special instructions on the SWP:

  - Industrial hygiene staff were not contacted to survey the cell prior to the commencement of work activities.

  - Industrial hygiene surveys were not performed in the cell to evaluate associated hazards.

- OSHA regulations require that personal protective equipment be used appropriate for the hazards being encountered.

  - No personal protective equipment was mandated on the SWP for the fire hazards associated with the work being performed on the day of the accident.

  - Neither LMES Procedure ESS-FP-111, "Welding, Burning, and Hotwork Fire and Health Protection," Revision 1, dated April 11, 1994, nor a safety bulletin issued by the DOE Office of Environment, Safety and Health (EH) in June 1991 (*Fire Prevention Measures for Cutting/Welding Activities*, DOE/EH-0196, Bulletin 91-3) addresses personal protective equipment. In addition, the EH Bulletin focuses only on property loss prevention rather than on personnel protection.

- LMES Procedure ESS-FP-111, Revision 1, applies to all welding, burning, or hotwork operations conducted at LMES sites for construction, repair, or maintenance activities and establishes requirements for ensuring that an effective control program is in place to prevent injury, loss of life, and property damage from fire, as well as adverse health effects initiated by welding, burning, or hotwork operations. A review of this procedure revealed:

- The requirement to identify a fire watch for all welding, burning, or hotwork operations is identified, but personnel-monitoring responsibilities for the fire watch during operations are not specified.

- The requirement for maintaining a line of sight with the workers at a distance that would enable timely emergency response is not addressed.

- Immediate first-aid response or any fire-extinguishing techniques, other than the use of fire extinguishers (e.g., fire blankets, drop-and-roll technique) are not addressed.

- The use of radios or other devices for fire watches during emergency situations is not addressed.

- A designated fire watch was not assigned or listed on the Burning Permit by the Service Supervisor.

■ The Service Supervisor did not inspect the cell and verify that all precautions were taken prior to initiation of work on the day of the accident.

A Job Hazards Analysis is a tool for systematically identifying the hazards associated with the individual steps of an identified activity/operation, documenting the preventive measures taken to control each hazard, and planning mitigation strategies for imminent danger scenarios. An SWP is required to establish safety boundaries and controls to ensure that adequate protection is provided for workers performing specified work that creates the potential for special or unusual hazards. The responsibilities, minimum requirements, and guidelines for preparing, approving, issuing, and using an SWP at the K-33 Building are described in K-25 Site Procedure SPP-5401. Cross-references to other associated procedures and work control processes, such as the Job Hazards Analysis and Burning Permit, are identified in Procedure SPP-5401.

Work performed on the day of the accident was not in accordance with applicable procedures (Procedures SPP-5401 and ESS-FP-111, Revision 1). Potential job hazards were not identified through a Job Hazards Analysis, the condition of the work area inside the cell was not adequately evaluated by ES&H disciplines and the Service Supervisor, and mitigation actions for emergency situations were unclear and/or were nonexistent. A designated fire watch was neither assigned for the job nor listed on the Burning Permit; also,

the role of the designated fire watch was not clearly defined in procedures.

Failure to provide adequate procedures and to effectively implement them at all levels of LMES prevented a clear understanding of expectations and the associated requirements. A Job Hazards Analysis could have identified specific safety hazards and mitigation strategies for the work performed on February 13, 1997. The failure to use a designated fire watch contributed to the Welder's delayed detection of the fire hazard. In addition, failure to follow the existing procedures for completing and using the required SWP and Job Hazards Analysis, in addition to inadequate supervision and monitoring of the work activities, led to conditions in which all hazards were not identified and were therefore unmitigated.

Procedural inadequacies and failure to follow procedures allowed hazards to remain unidentified and unmitigated.

2.2.4 Human Factors, Training, and Qualifications

The LMES Burning Permit and fire watch processes in place include training and procedures for work like that being performed on February 13, 1997. Review of training lesson plans and procedures revealed that, in some instances, the lesson plans contained detailed instructions that were not in the procedures.

The training for the Burning Permit process indicates that one responsibility of service supervisors is to personally inspect the work area to ensure that all precautions are fully implemented. Following this inspection, the "verified" column on the Permit is to be completed.

Some fire watch instructions that appear in training do not appear in procedures.

Fire watch training for welding, burning, and hotwork includes detailed instructions for fire watches. The training includes instructions that if the fire watch leaves the work site, he/she should stop all burning, welding, and hotwork, or otherwise ensure that another fire watch is assigned to the work site. However, this was not documented in LMES procedures, and there was no fire watch inside the cell at the time of the accident.

The Welder's training was up-to-date. The Welder had no physical, mental, or other impediments that impacted his performance. The Welder's peripheral vision and sense of smell were impaired by the requirement to wear a full-face respirator under a welder's mask while he was working (see Exhibit 2-3). The two sets of anti-contamination coveralls, in conjunction with the blue general-purpose coveralls, resulted in a bulky garment with many folds and creases that could have captured sparks or molten slag produced from the cutting/welding process (see Exhibit 2-1). Further, his

ability to recognize (by sensing heat) that he was on fire was reduced by the multiple layers of clothing, which provided insulation when the outer coverall ignited. This was confirmed in interviews with other welders, who indicated that because of their personal protective equipment, including respirator and welder's mask, they invariably feel the heat of the fire before they see it.

The victim's ability to sense a fire was limited by his protective equipment.

Training Module 11655 states that supervisors are to "inspect the area where the burning and welding will be done." The Board located three Burning Permits issued for this job, dated February 11, 12, and 13, 1997. The Service Supervisor logged onto the Radiation Work Permit for this job only on February 11 and 12, 1997. Therefore, the Service Supervisor could not have inspected the work area on February 13, as indicated on the Permit. However, the training did not indicate that this inspection must be done every time a permit is issued. If conditions change or additional hazards are present, they would not be addressed on the permit and/or by the supervisor unless his inspection was done on a daily basis. The day before the accident, the Welder's anti-contamination coveralls caught fire, and a coworker extinguished the fire before it caused injury. This was not reported, so no new special instructions or additional guidance were entered on the Permit used on the day of the accident to address this unrecognized hazard.

The work area was not inspected prior to signing the permits, and relevant safety incidents were not reported.

Interviews conducted with employees revealed uncertainty concerning job security at K-25 due to downsizing and reorganization. The work force at K-25 is getting smaller, and employees' concerns about retaining their jobs may be a deterrent to reporting incidents of clothing fires that do not result in injuries. Because of the downsizing and LMES reorganization, there may also be a decrease in the workers' ability to focus on the job at hand.

Concerns about job security may have affected incident reporting.

Exhibit 2-3. Welder's Outfit with Hood and Respirator (Closeup)

Review of training records for employees present at the time of, or involved in, the accident indicated that fire watch training had lapsed (expired August 20, 1994) for one of the maintenance mechanics present at the job site. The Facility Managers/Service Supervisors Training Module (11655) advises supervisors that fire watches should be trained annually. The Service Supervisor who was assigned to the work had not completed the Facility Managers/Service Supervisors training, which addresses responsibilities of supervisors/issuing authorities who complete Burning Permits. However, the training is not specific enough to ensure that supervisors/issuing authorities understand what fulfilling these responsibilities means (i.e., verifying that precautions are implemented, identifying a fire watch), nor is this training required. It is only recommended training. Therefore, neither the Service Supervisor nor the Issuing Authority was trained on the importance of identifying a fire watch and documenting it on the permit.

Fire watch training for supervisors and issuing authorities is not required; therefore, responsibilities are not well understood.

The duties of the fire watch were not being carried out according to LMES training doctrine during the time the work was being done; neither the responsible Service Supervisor nor the Issuing Authority had completed the recommended training to facilitate understanding of their job responsibilities. Thus, another administrative barrier that could have prevented the accident was not in place.

The combination of personal protective equipment that restricted sensory perception and the lack of a designated fire watch